بسم الله الرحمن الرحيم

CHEMISTRY AND BIOLOGICAL ROLE OF CARBOHYDRATES IN THE BODY-II

LECTURE OUTLINE

By the end of the lecture, the student should know:

- **The formation of the ring structure.**
- **The glycosidic linkage.**
- **The functions and biological importance of polysaccharides.**

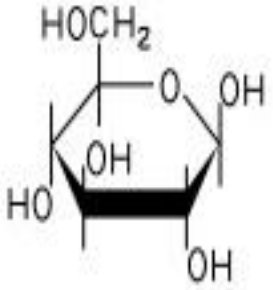
THE FORMATION OF THE RING STRUCTURE

- **Sugar molecules that have five or six carbons are flexible.**
- **If a six member sugar forms a ring between Carbon 1 and Carbon 5, it is called a pyranose ring**
- **If a six member sugar forms a ring between Carbon 1 and Carbon 4 it is called a furanose ring. (Also if the ring is formed between Carbon 2 and 5 in keto sugars)**

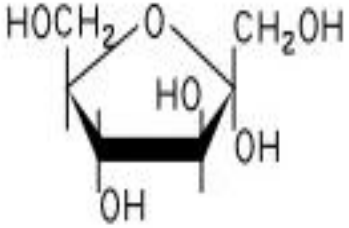
- Pyranose (6-membered ring) or furanose (5-membered ring) ring structures are based on the pyran and furan ring structure.

Pyran

Furan



Glucose
(Pyranose)



Fructose
(Furanose)

- **The flexible carbons in monosaccharides like glucose or fructose bring Aldehyde or Ketone Group close to the OH group of the same molecule and form a ring structure.**

- **If this ring is formed by an aldehyde group, it is called “Hemiacetal ring” or if it is formed by a keto group, it is called “Hemi Ketal Ring”**

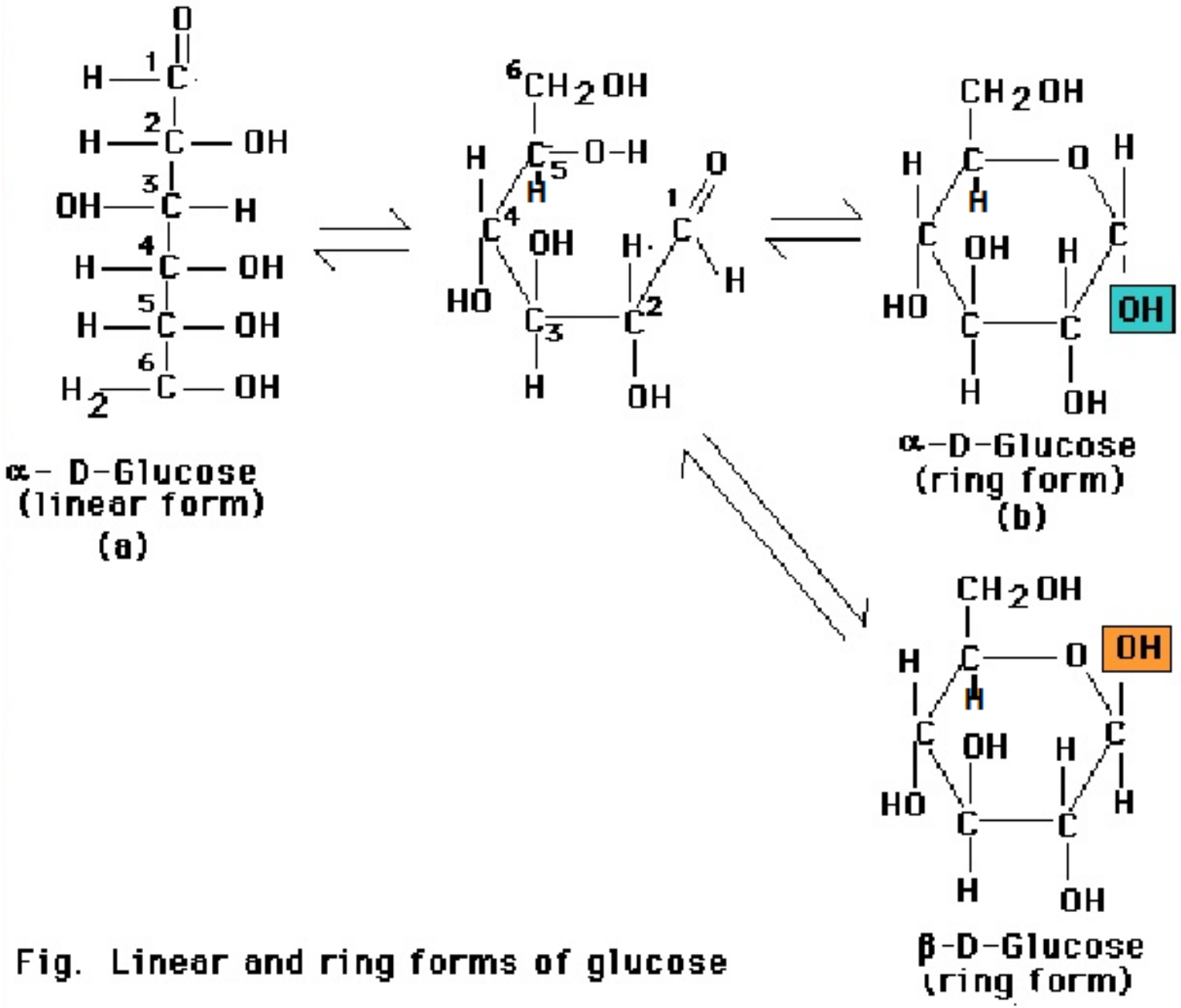
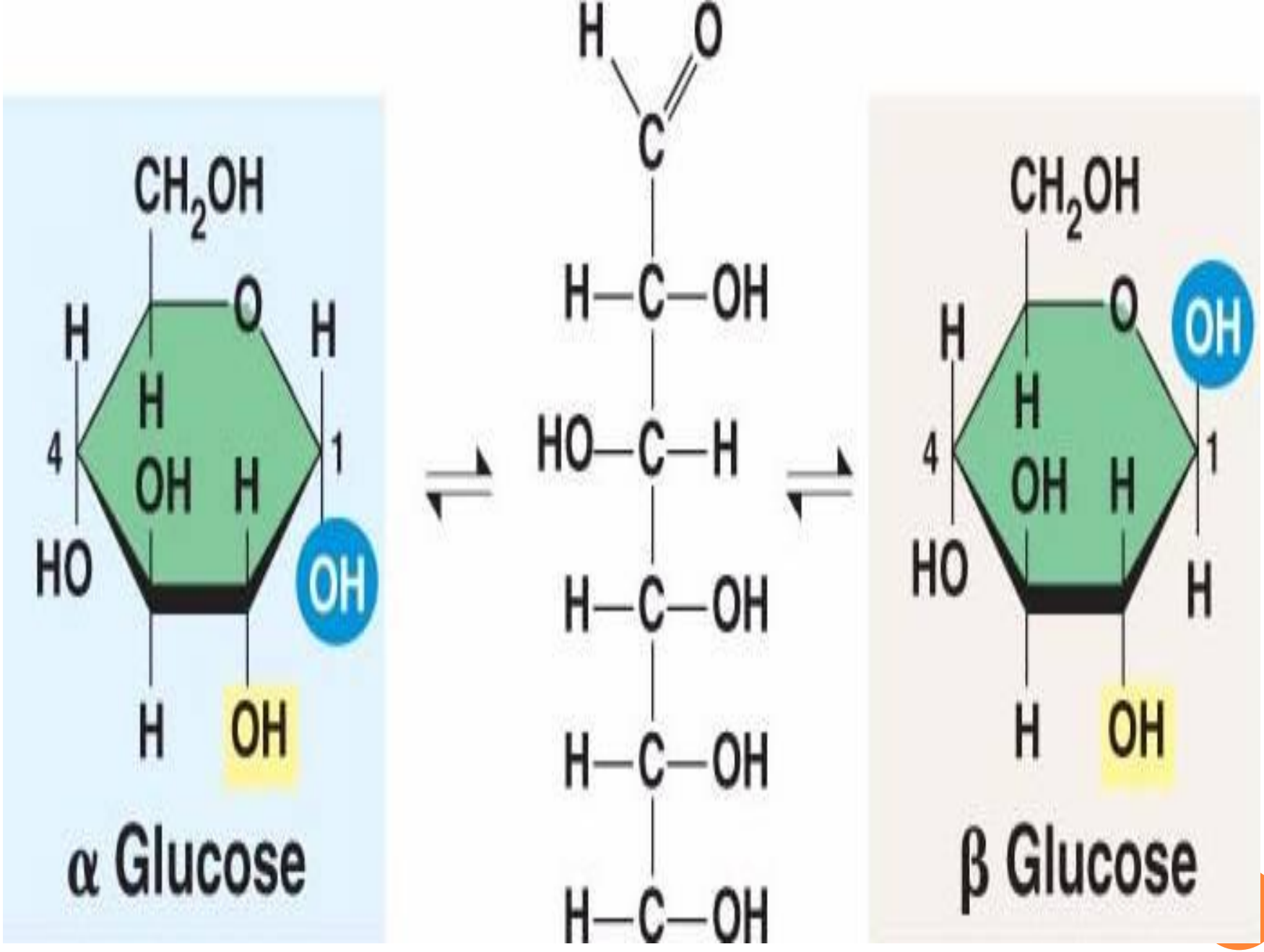


Fig. Linear and ring forms of glucose


CH2OH
O
H
H
H
4
OH
H
1
HO
OH
H
OH
α Glucose
H
O
C
H—C—OH
HO—C—H
H—C—OH
H—C—OH
H—C—OH
H—C—OH
CH2OH
O
OH
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OH
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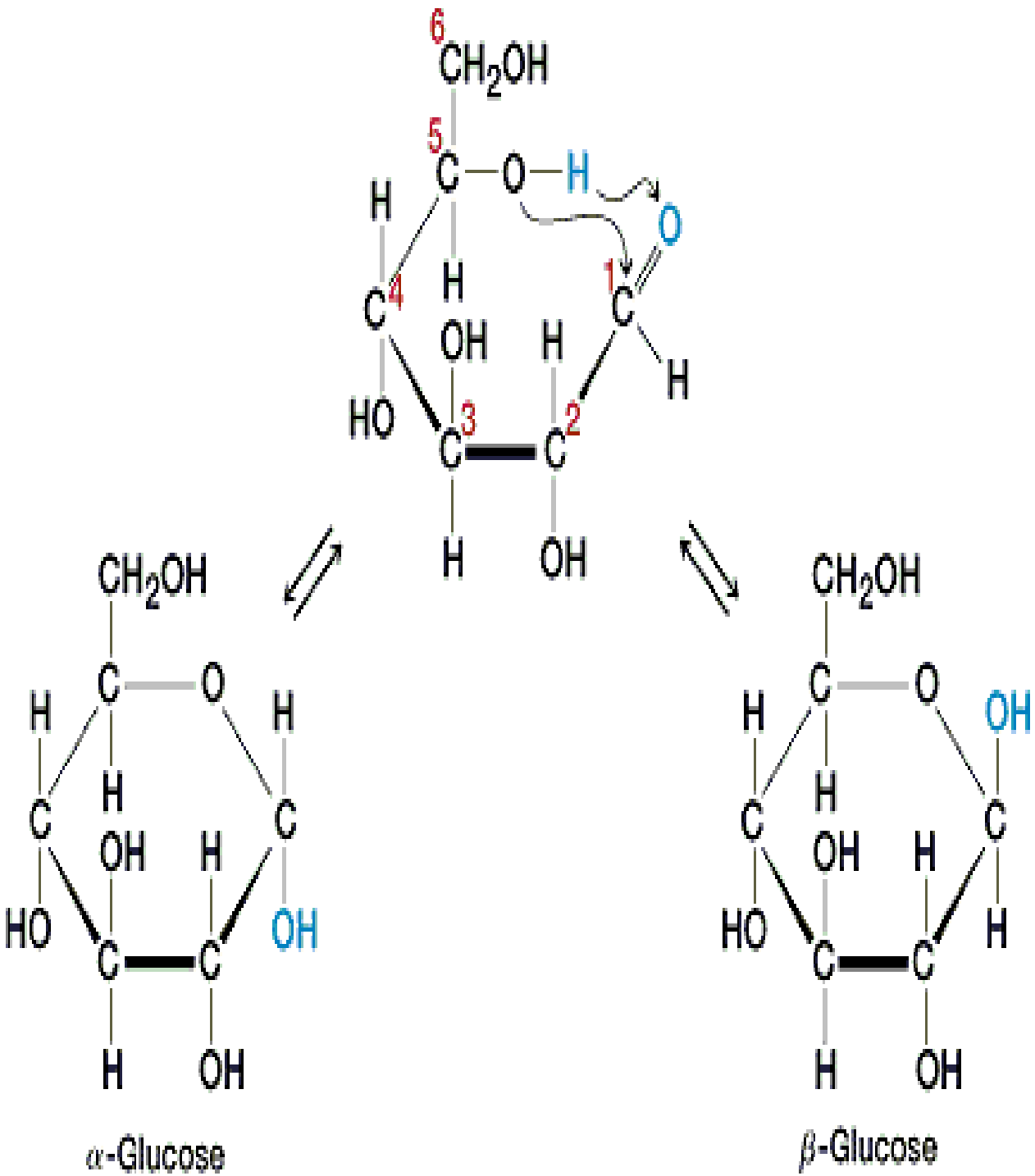
1
HO
H
H
OH
β Glucose

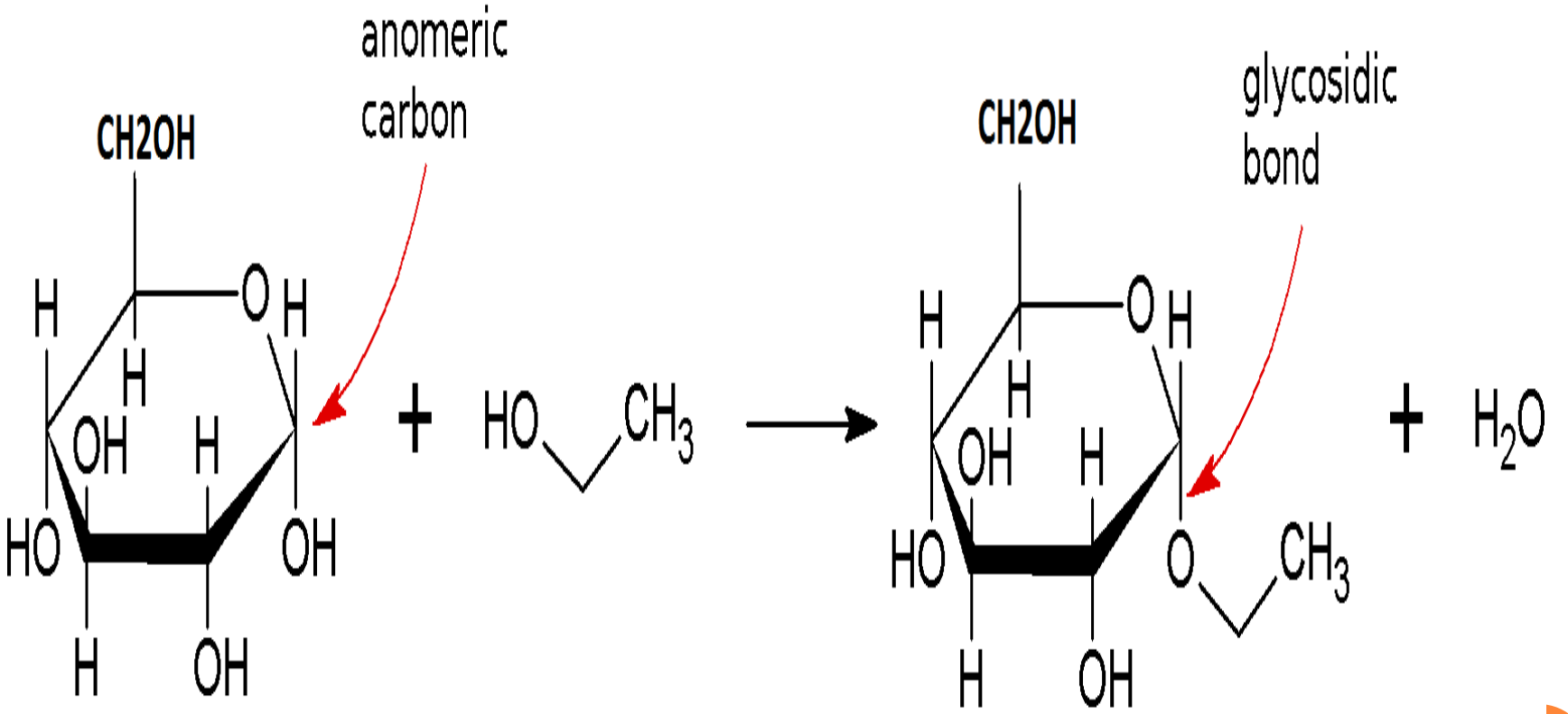


- The aldehyde group comes in close proximity to the hydroxyl group.
- The H of the hydroxyl group is transferred to the oxygen of the aldehyde group.
- The oxygen from the hydroxyl group forms a bond with the carbon of the aldehyde group.

Glycosides

- **Glycosides are compounds in which:**
  - **A Monosaccharide is attached to an Alcoholic group of a second compound By Glycosidic Linkage.**
- **Glycosidic Linkage is Defined as an:**
  - **Acetal Linkage Between Carbonyl Carbon of a Monosaccharide and Hydoxyl Group of an Another Compound.**

METHYL GLUCOSIDE

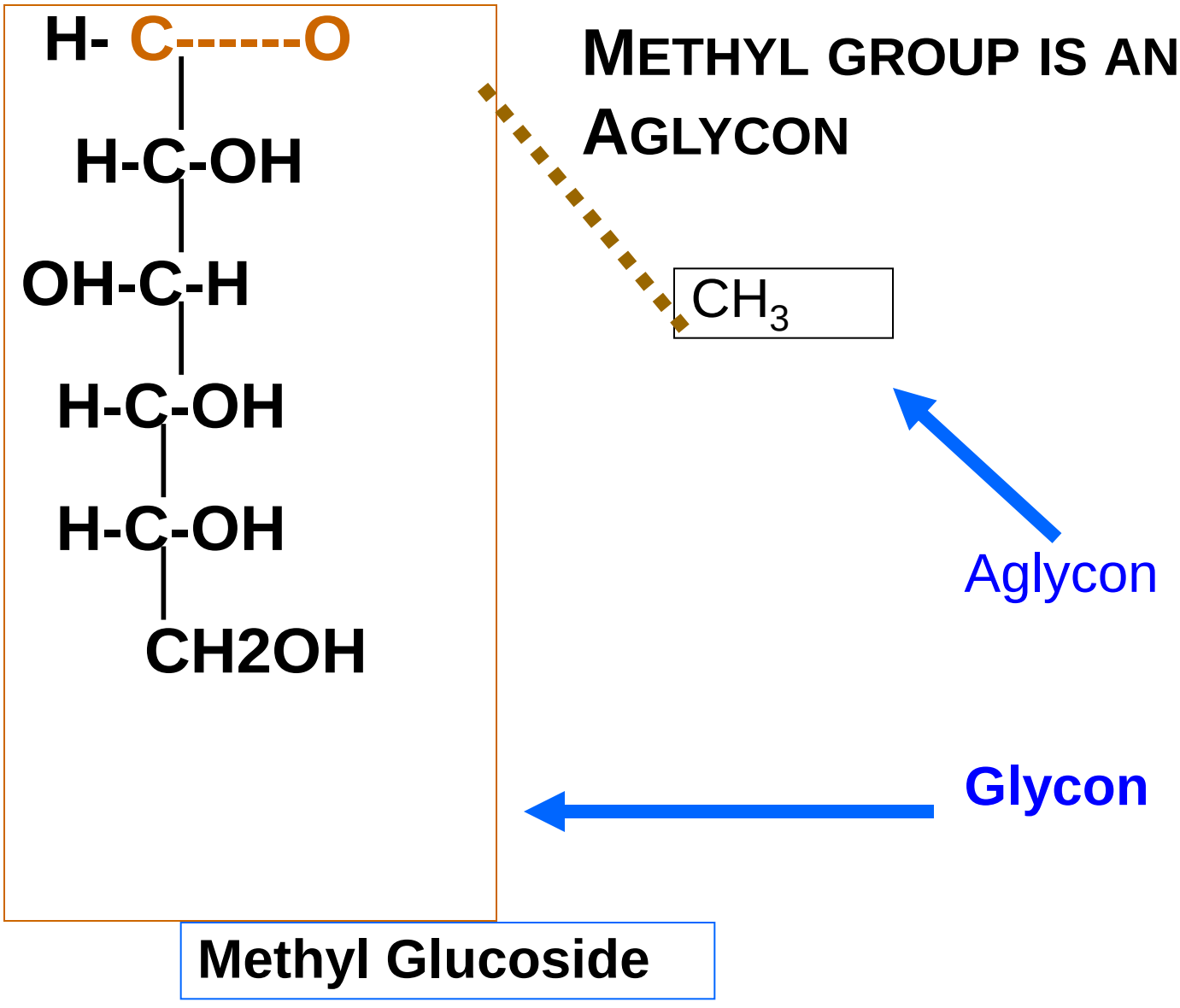


In Glycosides Other Compound May or May Not be a Monosaccharide

- When the alcoholic compound in a Glycoside is a Non-Carbohydrate it is called Aglycon.

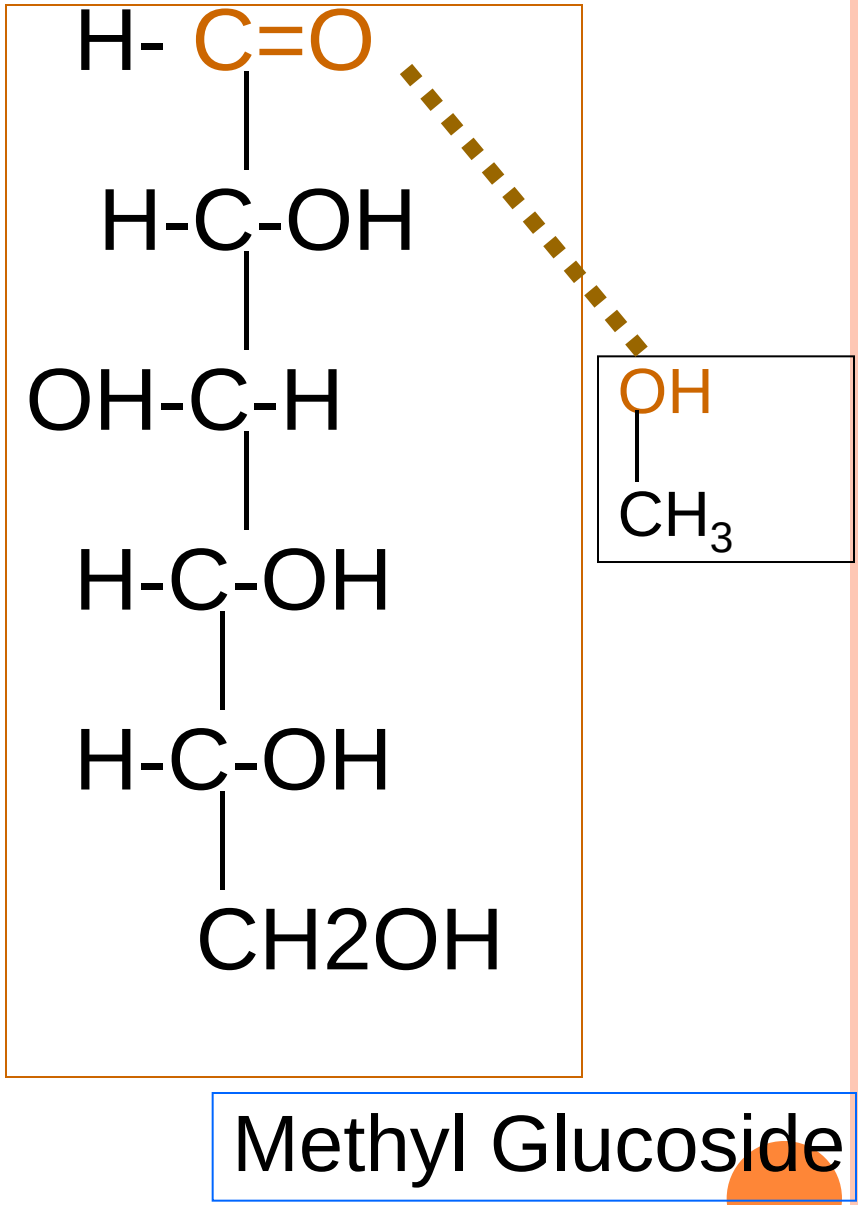
- In methyl Glucoside Methyl group is an Aglycon.

In methyl Glucoside Methyl group is an Aglycon



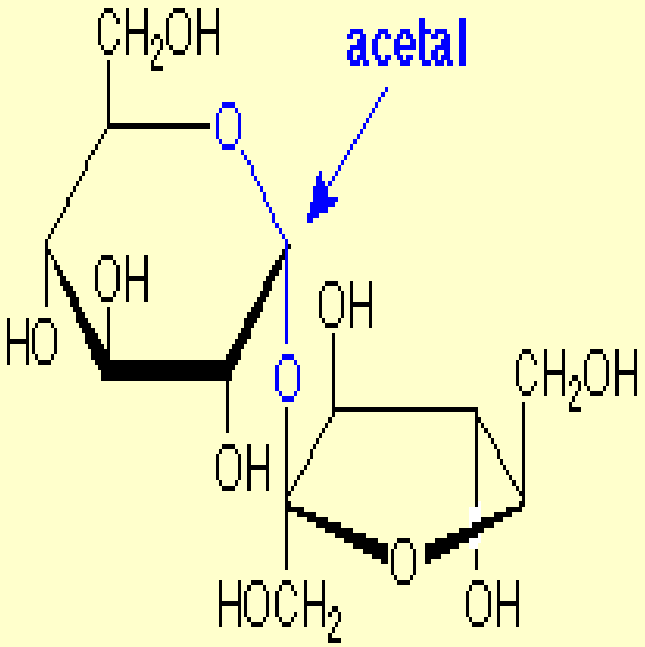
GLYCOSIDES

Carbonyl Carbon of a Monosaccharide is attached, by an Acetal linkage, to an Alcoholic group of a second compound.(Acetal is an organic molecule where two separate oxygen atoms are single bonded to a central oxygen atom)

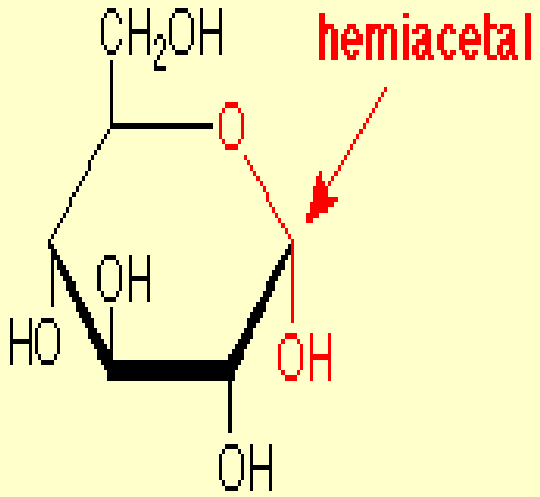


Methyl Glucoside

HEMIACETAL AND ACETAL

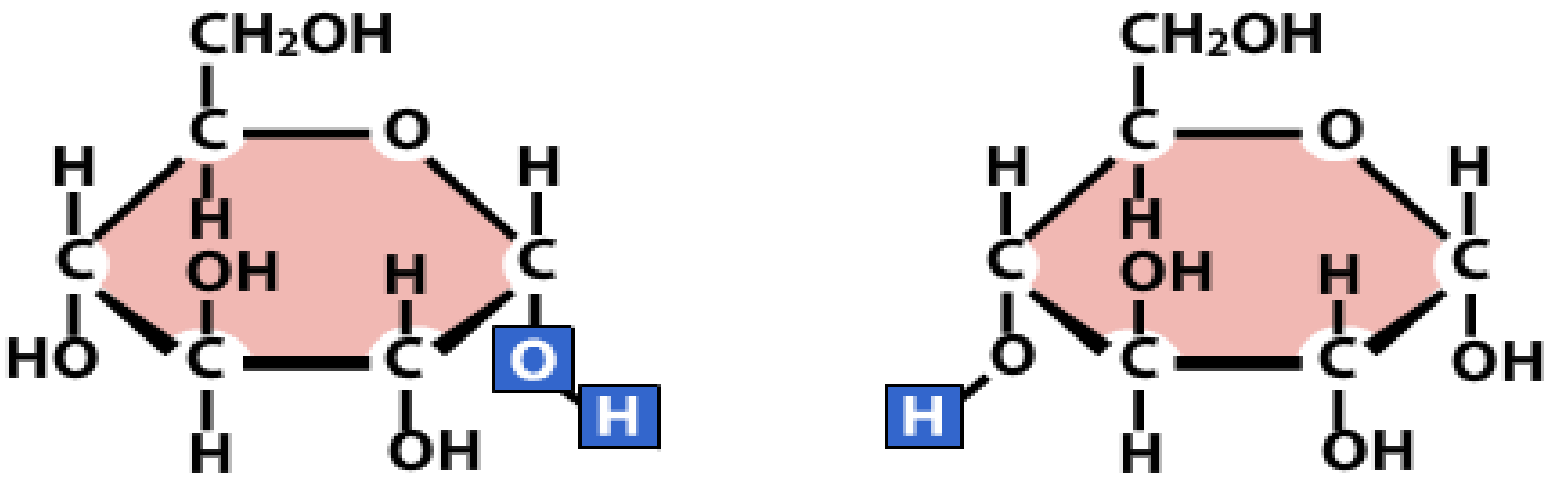


disaccharide (sucrose)



monosaccharide (glucose)

GLYCOSIDIC LINKAGE BEING FORMED BETWEEN TWO SUGARS



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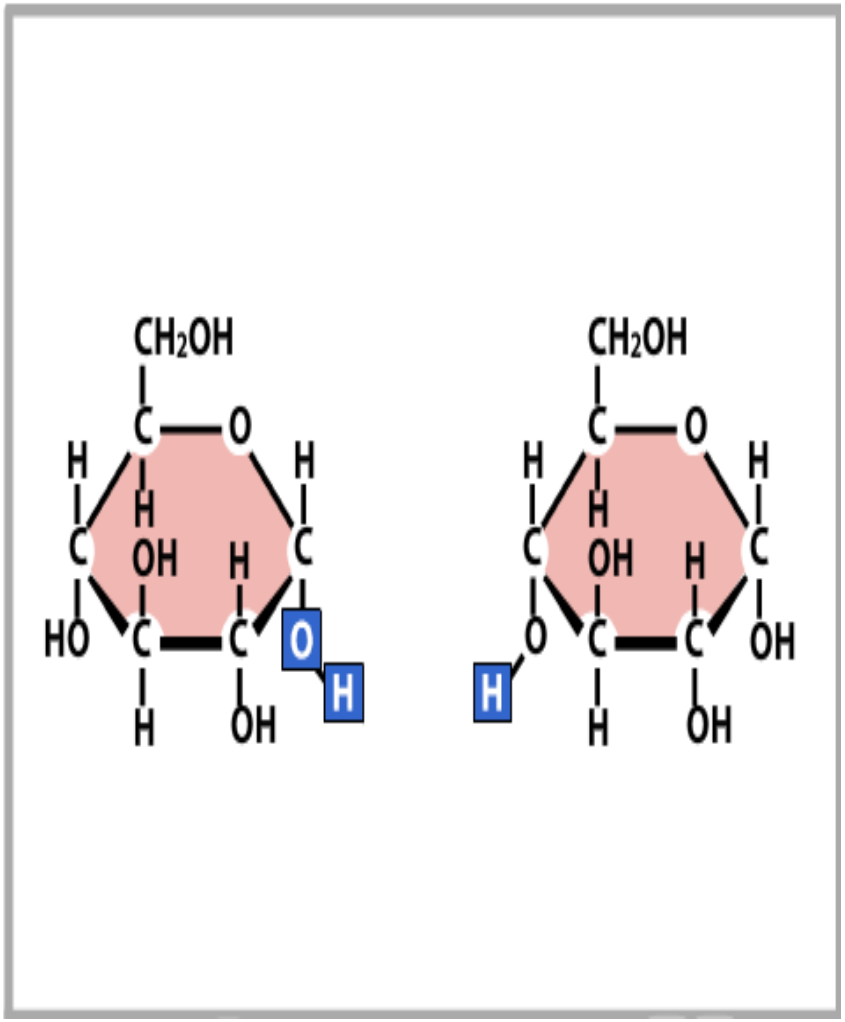
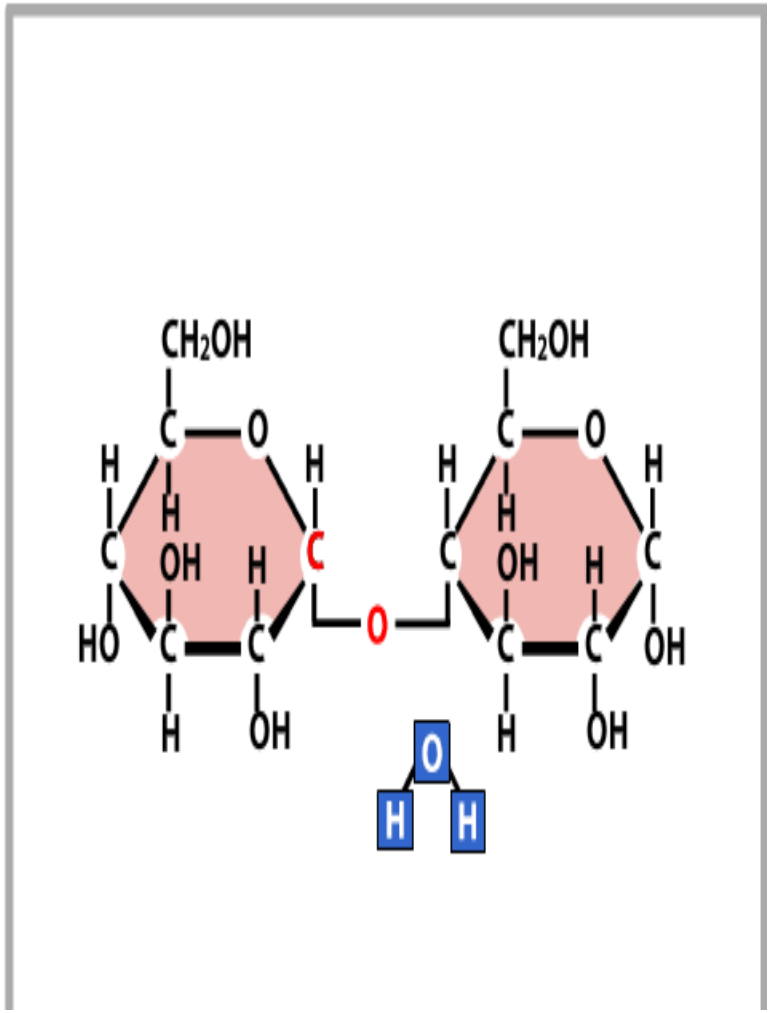




Types of Glycosidic Linkages

- In the formation of disaccharides, the type of glycosidic linkage formed is O Glycosidic Linkage.
- There are other glycosidic linkages as well which include S-glycosidic bonds, N- Glycosidic bonds.

POLYSACHHARIDES

- Most of the Carbohydrates found in nature occur in the form of high molecular weight complex compounds called POLYSACCHARIDES.
- Composed of ten or more monosaccharides or their derivatives.
- Monomer units are linked by the glycosidic (acetal) linkages.
- On Hydrolysis yield a large number of Monosaccharide units or their derivatives.

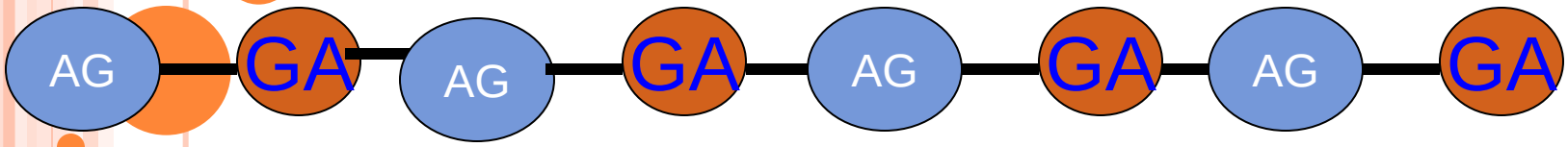
Polysaccharide may be Classified into two Groups

- **When polysaccharides are composed of a single type of monosaccharide building block, they are termed:**
  - **Homo polysaccharides or (Homo Glycans).**
- **Polysaccharides composed of more than one type of monosaccharide are termed:**
  - **Hetero polysaccharide or (Hetero Glycans).**

HOMOPOLYSACCHARIDES:

POLYSACCHARIDES MAY BE COMPOSED OF A SINGLE TYPE OF MONOSACCHARIDES

Or it may be composed of more than one type of Units



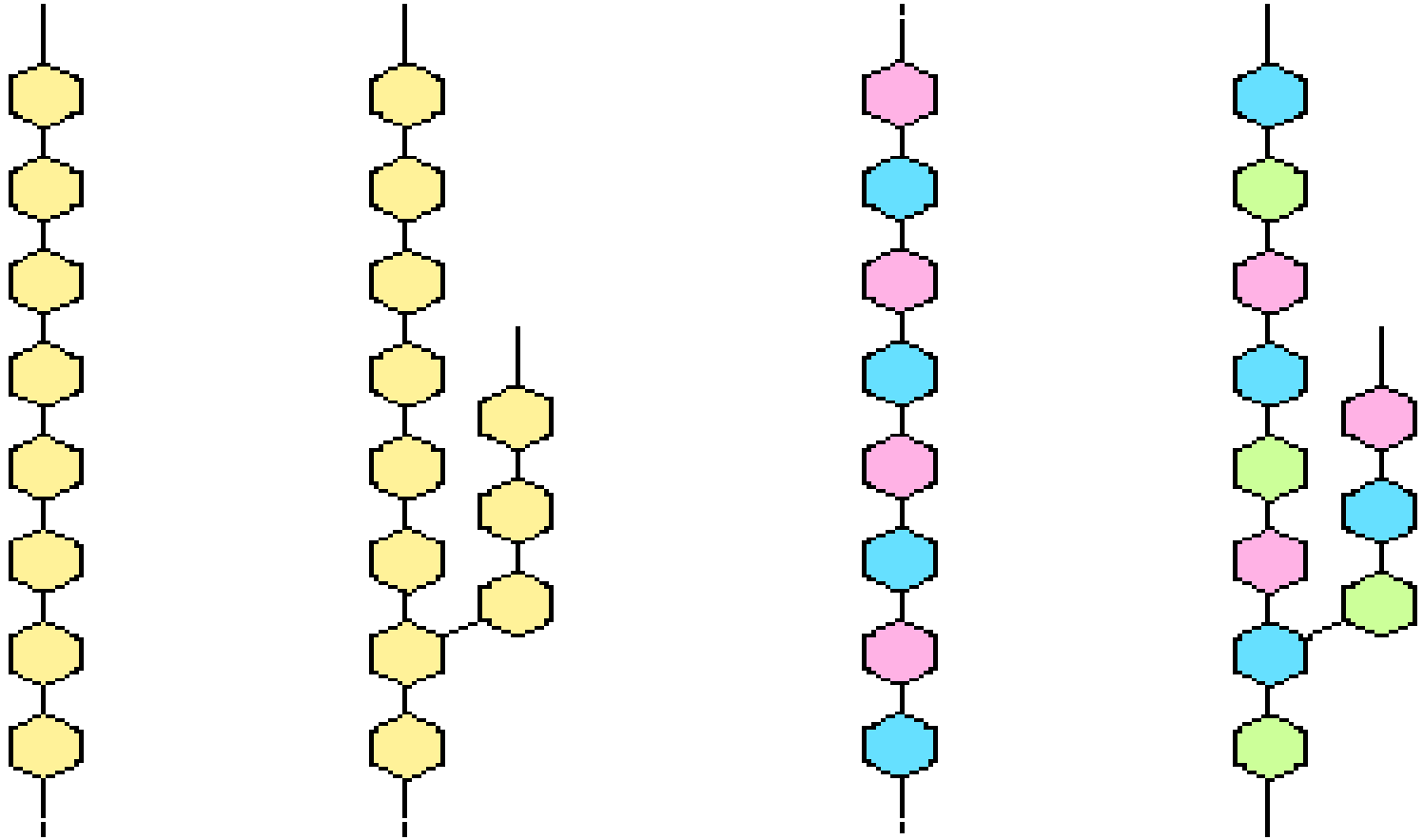
Homopolysaccharides

Unbranched Branched

Heteropolysaccharides

Two monomer types, unbranched

Multiple monomer types, branched

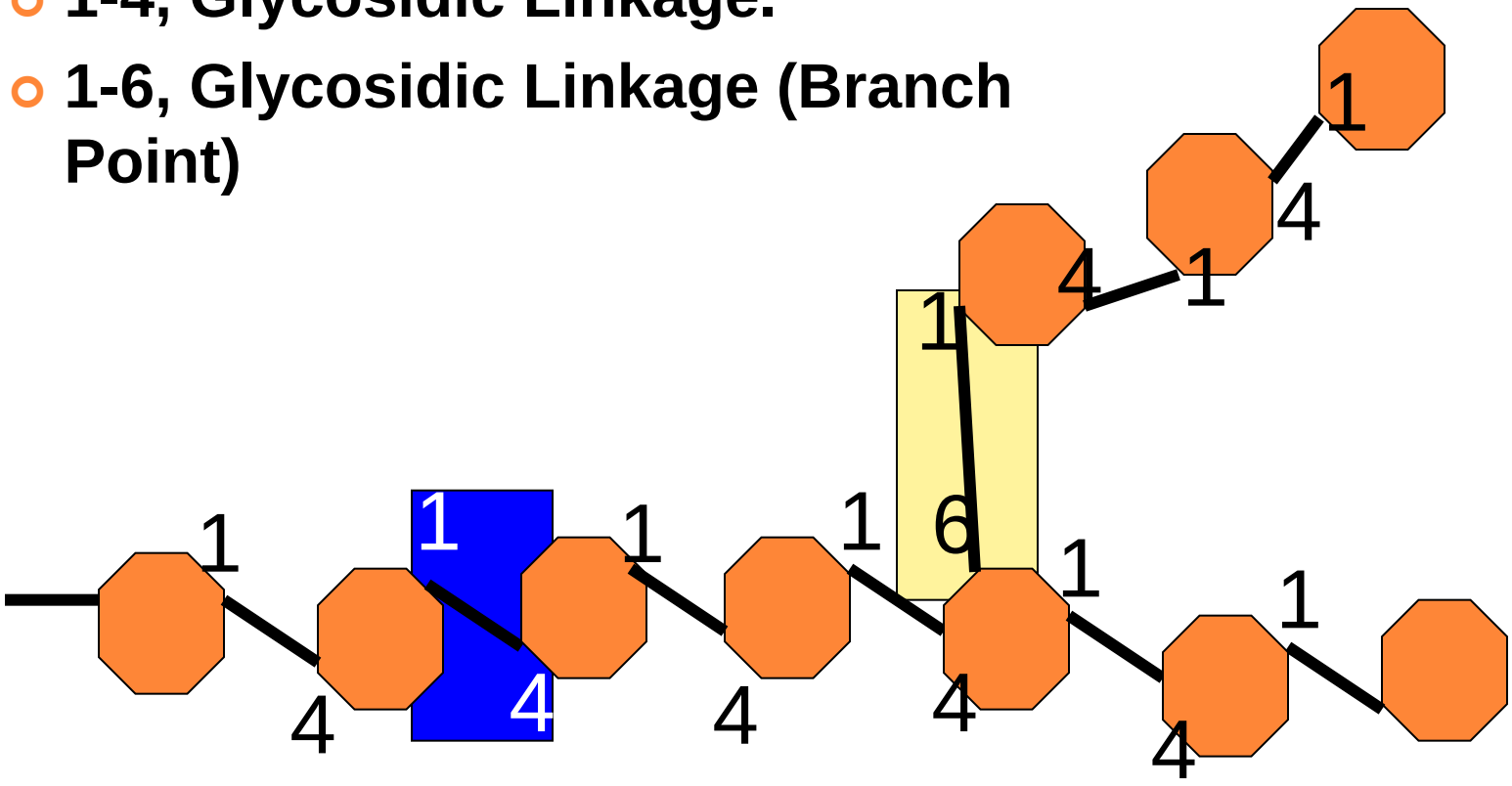


HOMOPOLYSACCHARIDES

- Polysaccharides which are composed of Similar Types of Monosaccharide Units.
- Common examples are:
  - Starch.
  - Glycogen.
  - Cellulose.
  - Dextrin.

Two types of Glycosidic Linkages in Glucose Polymers:

- 1-4, Glycosidic Linkage.
- 1-6, Glycosidic Linkage (Branch Point)



STARCH: A COMPLEX GLUCOSE POLYMER

- It is a homopolysaccharide comprising of molecules of glucose joined together by alpha 1,4 and alpha 1,6 linkages.
- It is made up of two polysaccharide units.

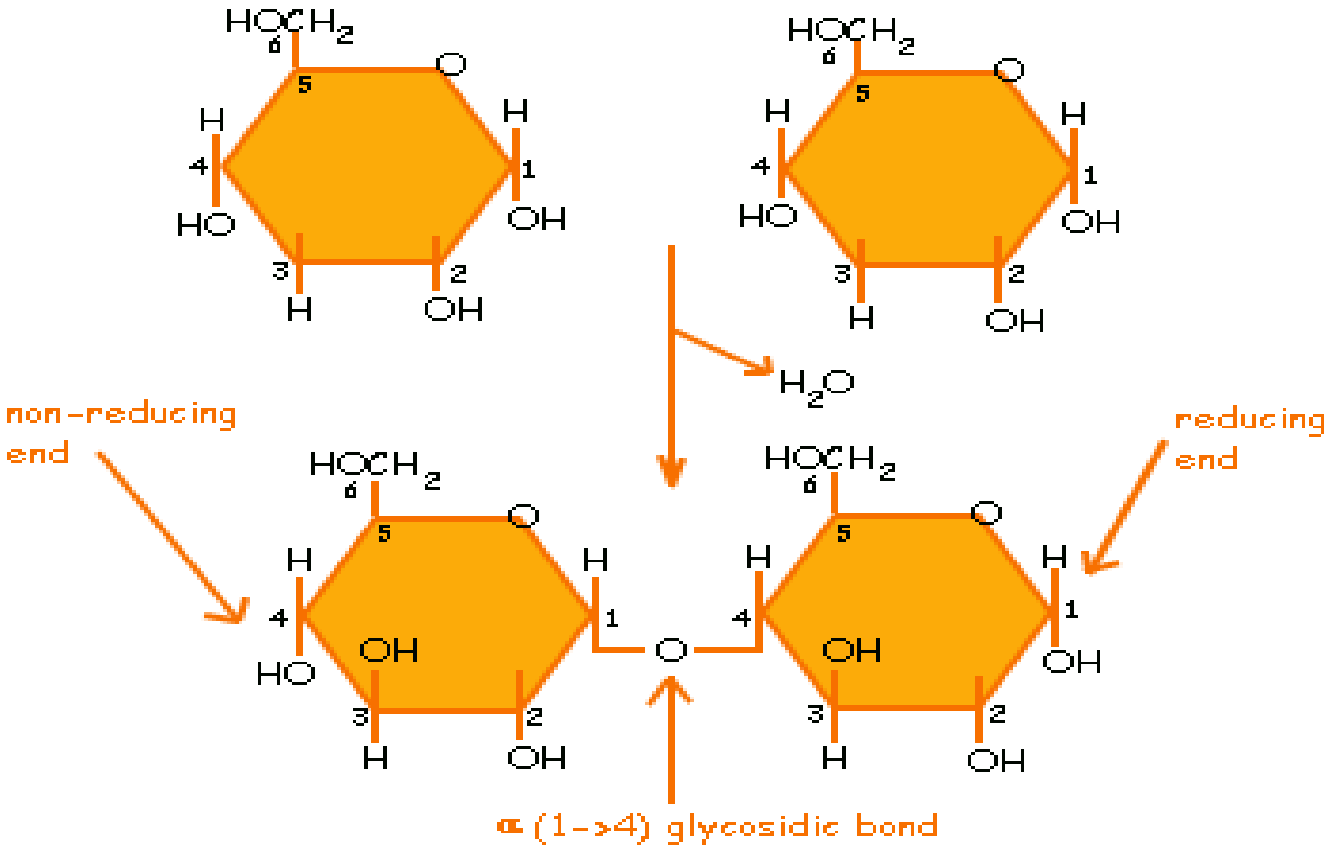
→AMYLOSE

→AMYLOPECTIN

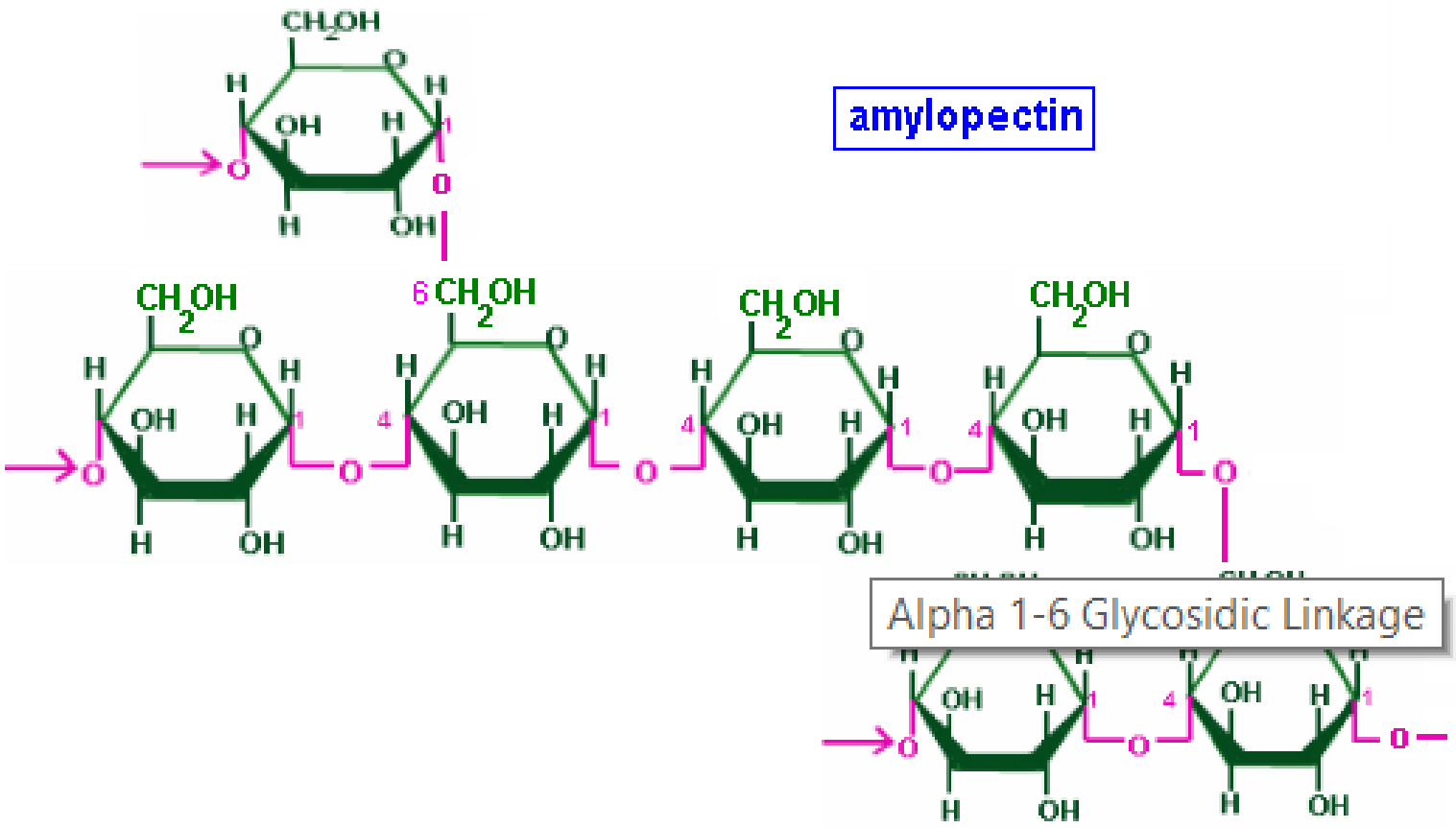
- **Amylose:**
  - **Straight Chain of Glucose molecules.**
  - **Having Only 1-4, Glycosidic Linkages.**

- **Amylopectin:**
  - **Complexed & highly Branched Polymer of Glucose.**
  - **Having Both 1-4 & 1-6, Linkages.**
    - **Linear Segment with 1-4 Linkage.**
    - **1-6, Linkages at Branch Points.**

ALPHA 1-4 LINKAGE

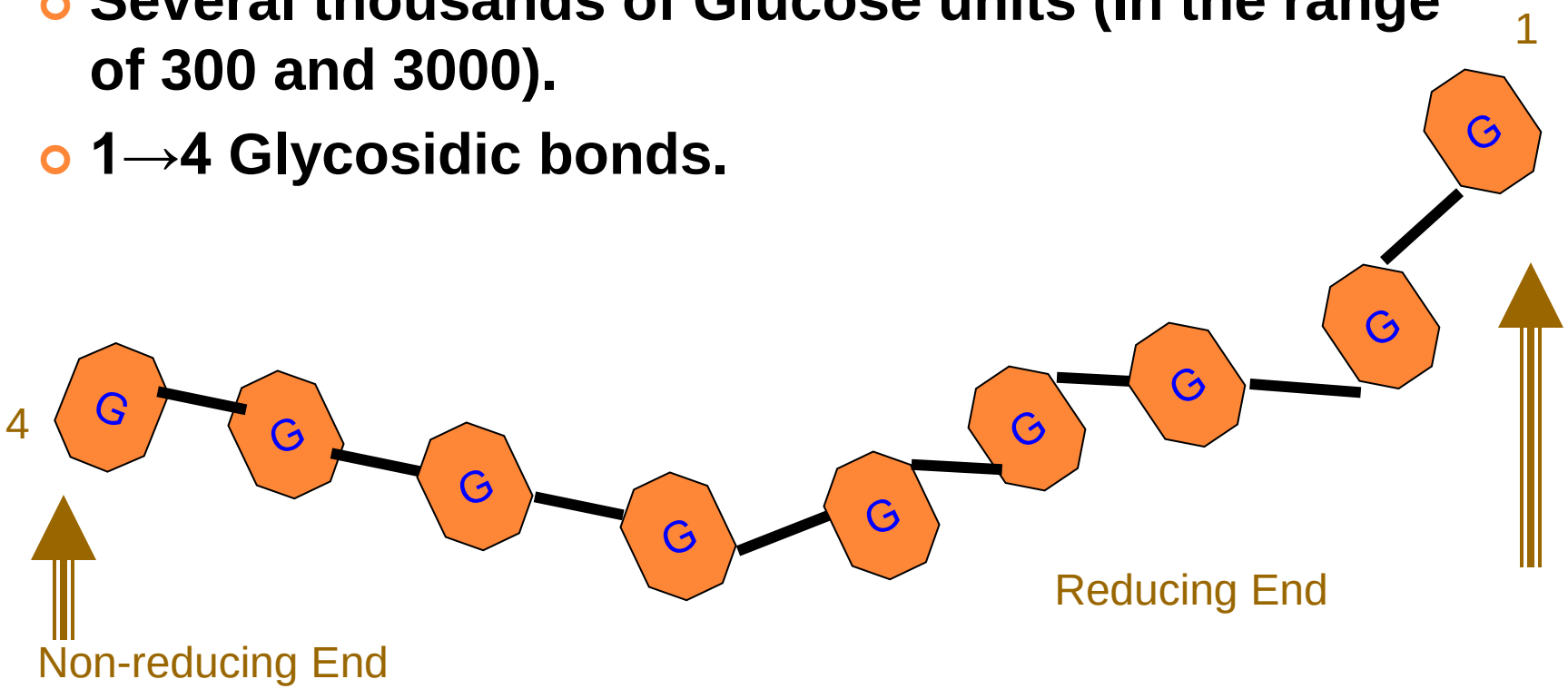


ALPHA 1-6 LINKAGE



Amylose; Unbranched Glucose Polymer

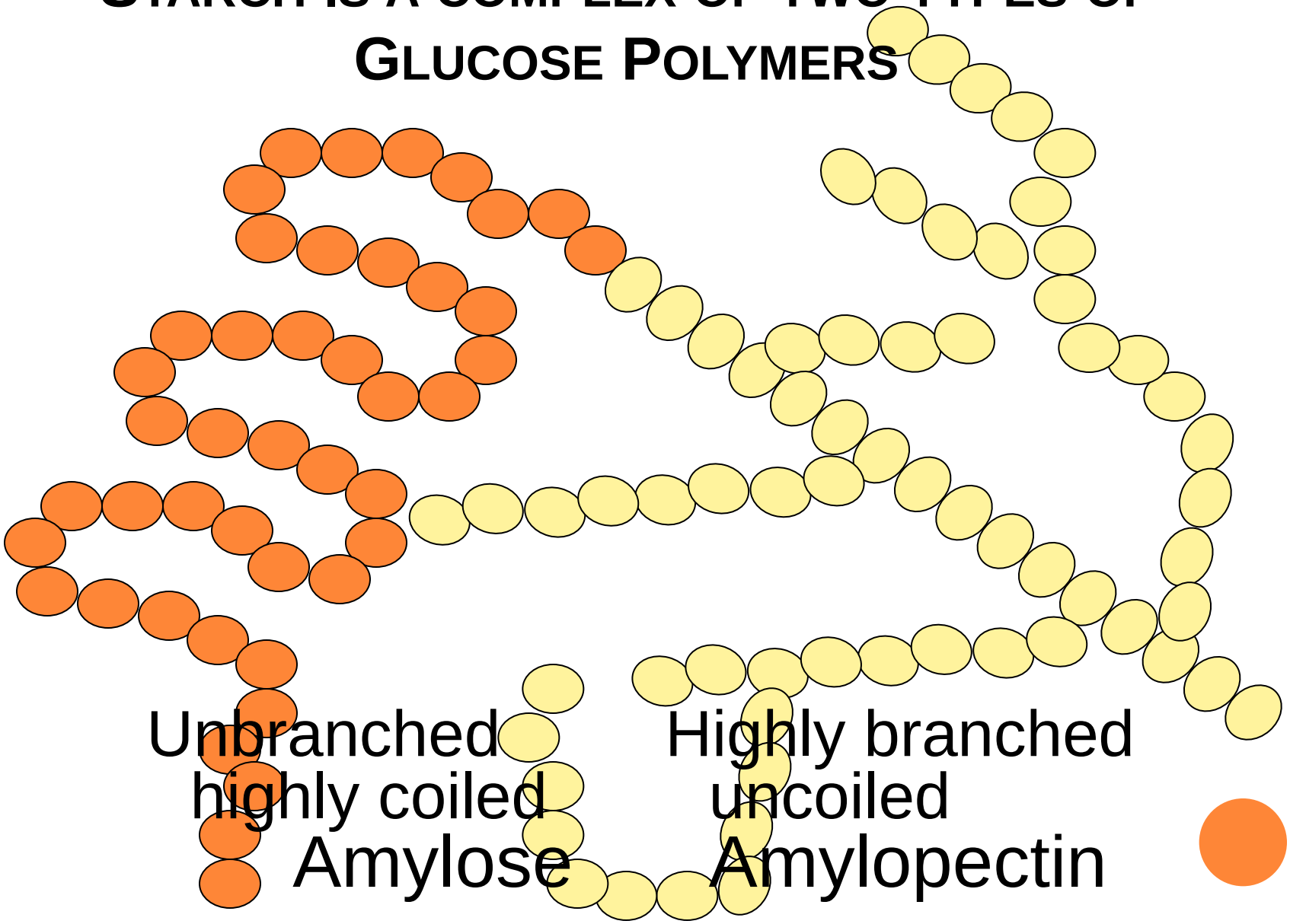
- Straight chain of Glucose molecules.
- Several thousands of Glucose units (In the range of 300 and 3000).
- 1→4 Glycosidic bonds.



Amylopectin; Complexed & highly Branched Polymer of Glucose.

- **Having Both 1-4 (Linear Segment) & 1-6, Linkages (Branch Points).**
- **Branching takes place with (1 → 6) bonds occurring every 24 to 30 glucose units.**
- **Formed of 2,000 to 200,000 glucose units.**

Starch is a complex of two types of Glucose Polymers



Starch; Mixture of two complex Carbohydrates

Amylose

- Forms about 25% of starch molecule.
- Unbranched
- Highly coiled

Amylopectin

- Forms about 75% of starch molecule.
- Highly branched
- Uncoiled.

Starch; Dietary Sources

- In human diet Starch is commonly obtained from:
  - Cereals (Rice, Wheat, and Corn)
  - Potatoes and sweet potato.
  - Fruits such as Banana.

Starch: Biological significance

- **Major form of stored carbohydrate in plant cells.**
  - **Plants store starch within specialized organelles called Amyloplasts.**
  - **When energy is needed for cell work, the plant hydrolyzes the starch releasing the glucose.**
- **Humans also have enzymes to hydrolyze (Digest) starch.**

- **Principle dietary carbohydrate.**
  - **In terms of human nutrition, starch is by far the most important of the polysaccharides.**
  - **It constitutes more than half the carbohydrates even in many affluent diets, and much more in poorer diets.**

- **Major source of Glucose (Metabolic fuel).**

Dextrins are Partially Hydrolysed Starch

- Intermediate products of hydrolysis of starch by acids or Amylase.
- Similar to starch but less complex and having lower molecular weight.
- Dextrin occurs in all starch producing parts of plants as an intermediate of starch synthesis or break down.

Glycogen

- Polymer of about 60,000 Glucose residues.
- Structure similar to Starch, but is even more compact & highly branched.
- This compactness allows large amounts of energy to be stored in a small volume, with little effect on cellular osmolarity.
- Glycogen is the analogue of starch in plants, and is commonly referred to as animal starch.

Glycogen; Biological significance

- **Major form of storage of carbohydrates (energy store) in animal liver and muscles**
  - **Primary short term energy storage.**
  - **Forms an energy reserve that can be quickly mobilized to meet a sudden need for glucose (Energy)**

Only the Liver glycogen is the Source of blood Glucose and made available to other organs

- **Although the total amount of Glycogen in muscles exceeds that in liver, Only the stores in the liver can be made accessible to other organs.**

- **Muscle glycogen provides Glucose (Metabolic fuel) to muscles only during exercise.**

Cellulose Distribution

- Most abundant organic compound in the earth's biosphere is in cellulose.
- Cellulose is the primary structural component of green plants.
  - The primary cell wall of green plants is made of cellulose.
  - Wood is largely cellulose, while paper and cotton are nearly pure cellulose.

Cellulose Structure; Straight, Unbranched and Uncoiled Chain of Glucose

- **Glucose Polymer:**
  - **500 to 5000 Glucose units.**
  - **Glucose units linked by β(1→4)-glycosidic bonds.**

Cellulose; Biological Significance

- It is a structural polysaccharide.
- The peculiar long fiber like structure contributes to their high tensile strength.
- Due to high tensile strength it is important in cell walls, where they provide rigidity to plant cells.

Nutritional Value of Cellulose is Insignificant in human beings

- Humans and many other animals lack an enzyme (Cellulase) to break the beta-linkages, so they do not digest cellulose.

- In the diets of humans Cellulose functions as roughage and is eliminated largely unchanged.

Cellulose; Clinical significance

- Cellulose is not digestible by humans and is often referred to as 'Dietary fiber' or 'Roughage’.
- Roughage acts as a bulking agent that increases the intestinal motility and helps propagating intestinal contents.
- Dietary Cellulose therefore prevents Constipation.

Hetropolysaccharides may be classified in three major groups

- **Mucopolysaccharides.**
- **Mucilages**
- **Hemicellulose**

MUCOPOLYSACCHARIDES

- **Composed of:**
  - **Amino Sugars and**
  - **Uronic Acids.**
- **Important examples are:**
  - **Hyaluronic Acid**
  - **Chondrotin**
  - **Heparin.**

Hyaluronic acid and Chondrotin are Important Components of Intercellular Matrix

- **Intercellular Matrix is the organic material filled in the intercellular spaces (So Called Ground substance).**
- **This organic matter is composed mainly of:**
  - **Collagen (Protein) and**
  - **Mucopolysaccharides.**

Intercellular Matrix (Ground Substance) Plays Many Important And Vital Roles:

- Cementing and strengthening substance for the tissue cells.
- Protective Barrier for the tissues.
- Holds the extracellular water and electrolytes in a homogenous distribution in the body.
- Intercellular Matrix is the Protective Barrier for the tissues.

→Any living or non living injurious substance when penetrates the tissue, they have to pass through the ground substance to reach the cells.

→The ground substance prevents the penetration of bacteria or any injurious agent in the tissue.

Major mucopolysaccharides of Ground substance are:

- Hyaluronic acid in soft tissues
- Chondrotin in hard tissues.

Hyaluronic Acid

- Long chain of alternate molecules of:
  - Glucuronic Acid And
  - N Acetyl Glucosamine.
- Hyaluronic Acid is Principally Found in Ground Substance Of the Soft Tissues e.g. Skin, Muscles, Liver and Synovial Fluid.

Biological importance of Hyaluronic Acid.

- **Being the component of ground substance It has a significant contribution in all the vital functions of Intercellular Matrix.**
- **Lubrication of Joints.**
  - **Hyaluronic acid present in the synovial joint spaces acts as lubricant and shock absorber.**

CHONDROTIN

- Mainly present in the Ground Substance of Bone and Cartilage.
- Polymer of N Acetyl Galactoseamine and Glucuronic Acid.
- They help in compressibility of cartilage and weight bearing.

Heparin

- **Polymer of:**
  - **Glucosamine Sulphate and**
  - **Glucuronic Acid Sulphate.**

- **IT is produced by mast cells.**

Heparin is a Natural Anticoagulant

- Heparin is a natural anticoagulant for the blood as it prevents the unnecessary and harmful intravascular coagulation of blood.
- Widely used as an anticoagulant drug.
- Secretion and action of Heparin as an Anticoagulant is one of Haemodynamic mechanisms which are responsible for the smooth blood flow.